Cleaning and Cleanliness Measurement of Additive Manufactured Parts

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EM22 – Material Test, Chemistry & Contamination Control Branch

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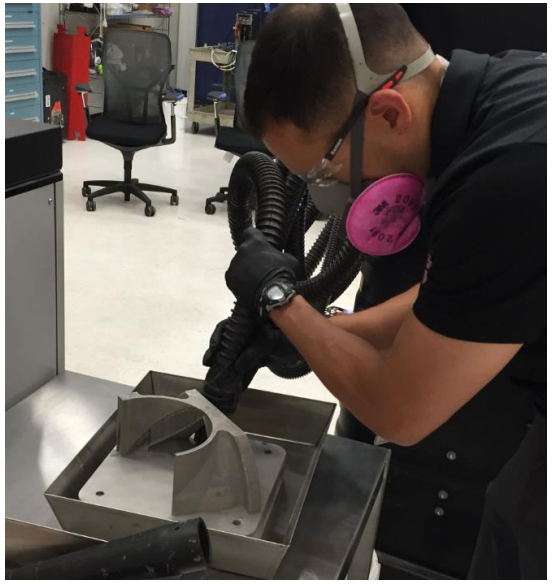
Additive Manufacturing

In Additive Manufacturing (AM), layers of material are deposited and selectively fused or melted to form a three dimensional part. Once completed, remnant material must be removed prior to post production processes. However, this can be difficult if the manufactured component has intricate cavities that can trap remnant bulk powder.

NASA MSFC has already encountered problems related to inadequate remnant powder removal. Case in point, blocked channels within AM components.

Selective Laser Sintering

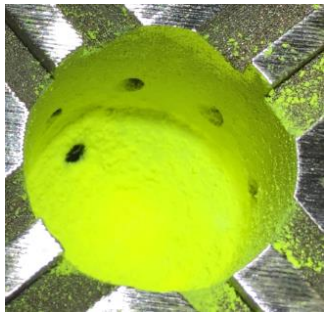


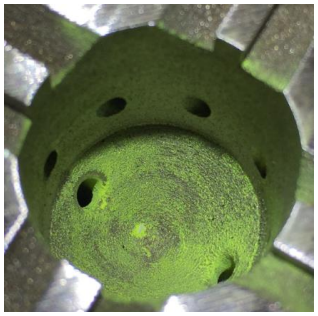
Post Sintering AM Remnant Powder Removal

Remnant Powder Permanently Trapped in Interior Cavities following Inadequate Cleaning & Post Thermal Processing

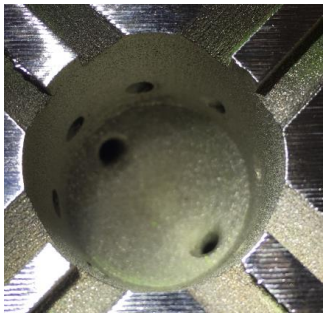
Standard Gross Remnant Powder Cleaning Methods

A) Vacuum VS. Compressed Air VS. CO_2 Snow


Doped


Vacuum


Compressed Air


CO2 Snow

Progression of cleanliness efficiency. (CO_2 Snow yielded the best results.)

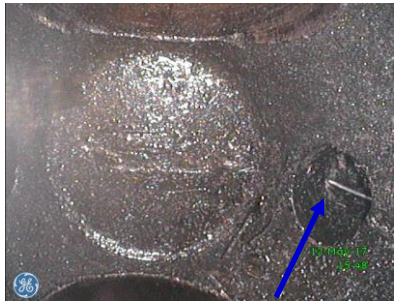
Pictures of various cleaning methods following fluorescent powder doping

B) Wire Probe / Endoscope

Utilized to remove large machined burrs that may be wedged within internal cavities.
Hard to remove from blind holes /deep recesses where wire may not be able to reach.
Compressed Air, CO_2 Snow, and even Ultrasonic Cleaning are ineffective.


Burrs Trapped in Machined Hole


Gradual Removal of Burr


Burrs Removed (Wire in View)


Relative Size of Burr

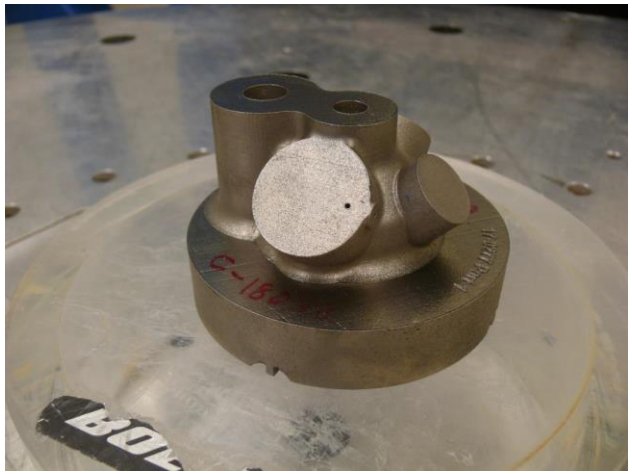
Computed Tomography Scan

Method Description:

- X-ray inspection technique that produces 70 cross-sectional slices (1 mm) of the test object, providing accurate geometric / dimensional characterization of internal structure & defects.
- Inspection is performed by rotating the test object between an x-ray source and detector array. Individual x-ray slices are taken while the object rotates. These slices can then be reconstructed into 3D volumes to show internal defects and structures.

Equipment:

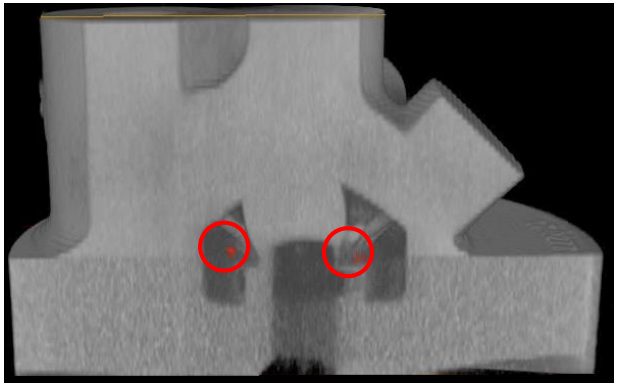
- 2 MeV linear accelerator and 450 KeV x-ray tube
- Linear x-ray detector array and amorphous silicon digital x-ray area detector
- Can accommodate objects up to 72” diameter/4000 lbs. on large system (spatial resolution of 0.010-0.030”) and up to 10” diameter/50 lbs. on small system (spatial resolution 0.005”)



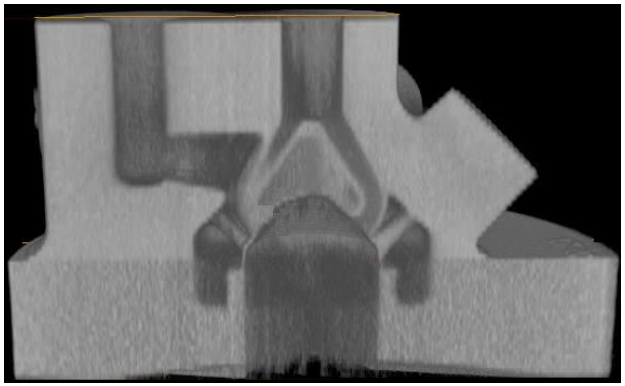
Component Loaded for CT Scanning

Component X-ray image

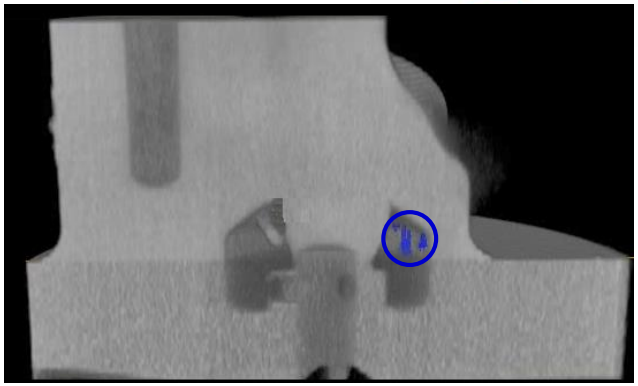
Component Analysis – Remnant Powder Locations



Front

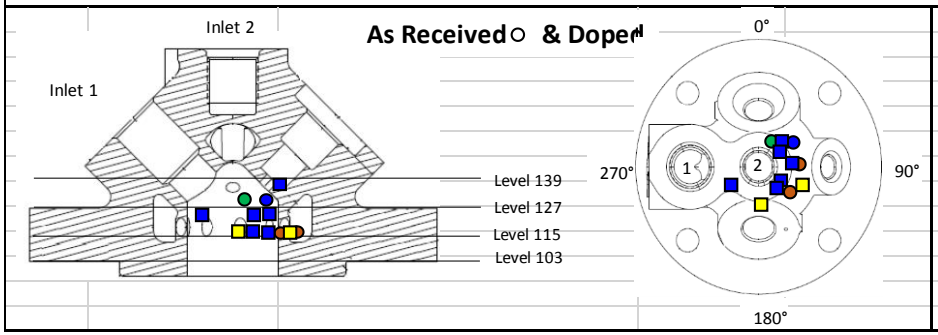


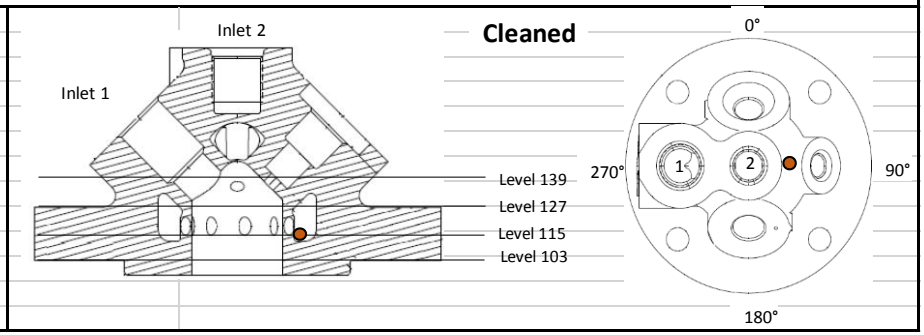
Center



Rear

#	Work Order	ASI #	Slice Height	# of Incidents	Observation of Powder
1	2017-V-0393	#1 - As Received	127 - 132	1	Chamber Side Wall, opposite Inlet 1 (40°)
2	2017-V-0413	#1 - Doped	*136*	*1*	*Chamber Internal Side Wall, below Inlet 2 (90°)*
3			127 - 132	1	Chamber Side Wall, opposite Inlet 1 (40°)
4			*125*	*3*	*Chamber Internal Side Wall (45°, 135° & 260°)*
5			*118*	*2*	*Chamber Bottom (45° & 135°)*
6	2017-V-0441	#1 - Cleaned			
7	2017-V-0398	#2 - As Received	118	2	Chamber, Interior & Exterior Wall (90° & 125°)
8	**2017-V-0448**	**#2 - Cleaned**	**118**	**1**	**Chamber, Interior Wall (90°)**
9	2017-V-0402	#3 - As Received	130 - 131	1	Chamber Side Wall, opposite Inlet 1 (10°)
10	2017-V-0453	#3 - Cleaned			
11	2017-V-0403	#4 - As Received / Doped	117 - 119	2	Chamber Bottom (100° & 180°)
12		#4 - Cleaned			

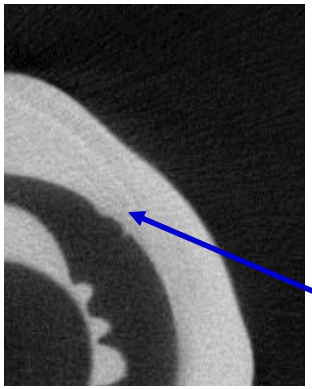


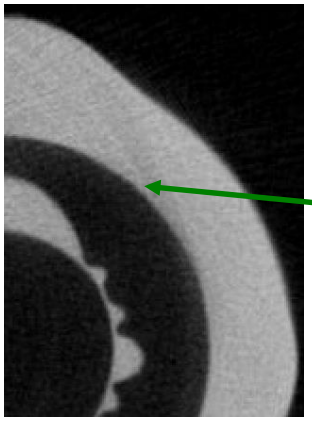


Component # 1 Analysis – As Received VS. Cleaned

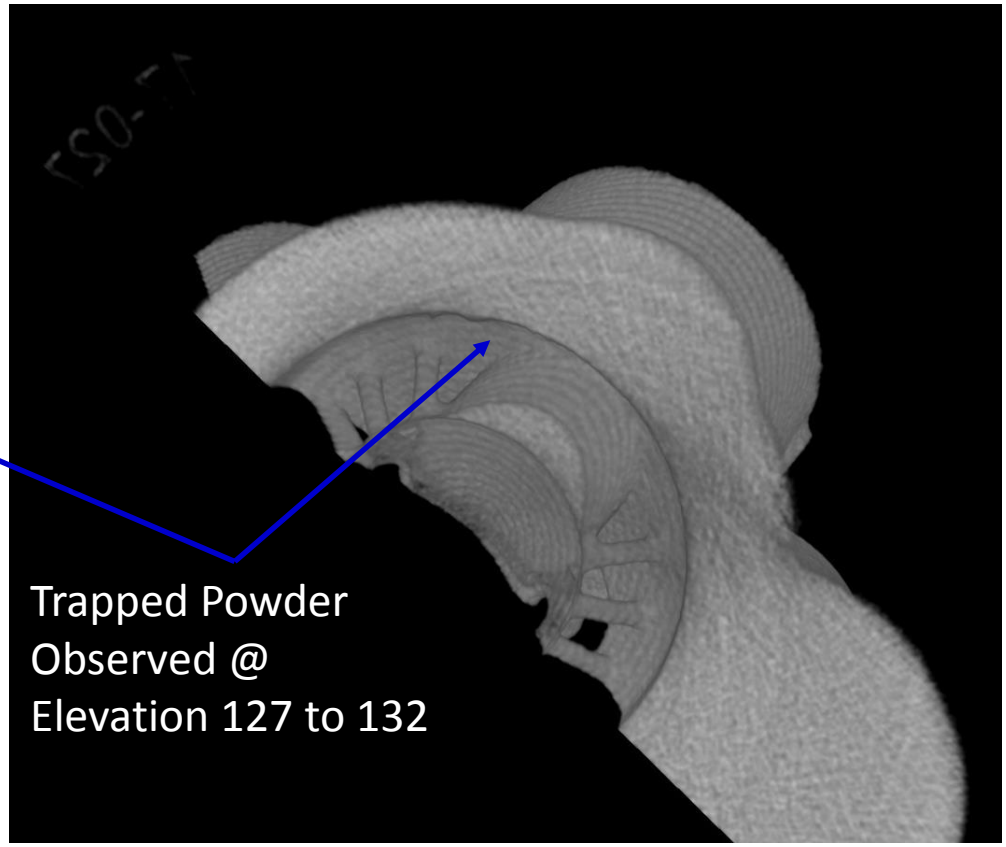
A total of four components were manufactured and cleaned using the prototype method. This method effectively removed process and doped powder from 11 of the 12 excursions.

Following CT analysis of the first component, where only one small patch of remnant powder was found, it was decided to dope half of the components for test capability.





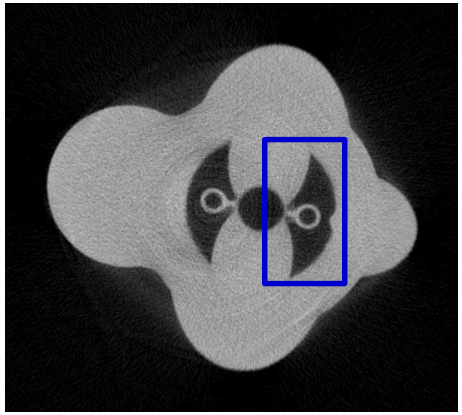
Cleaned Component, Powder Removed

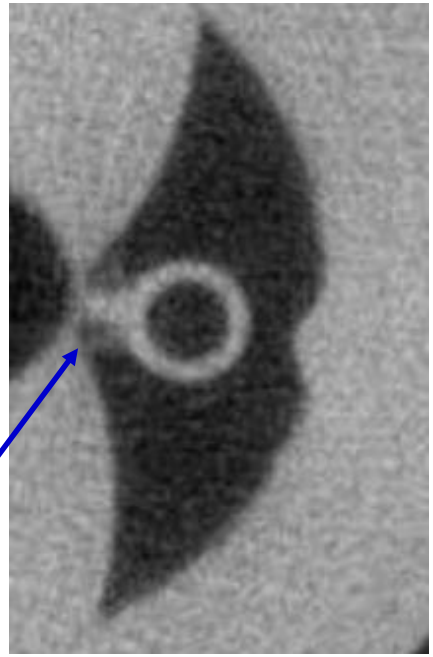


Component # 1 Analysis – Doped VS. Cleaned

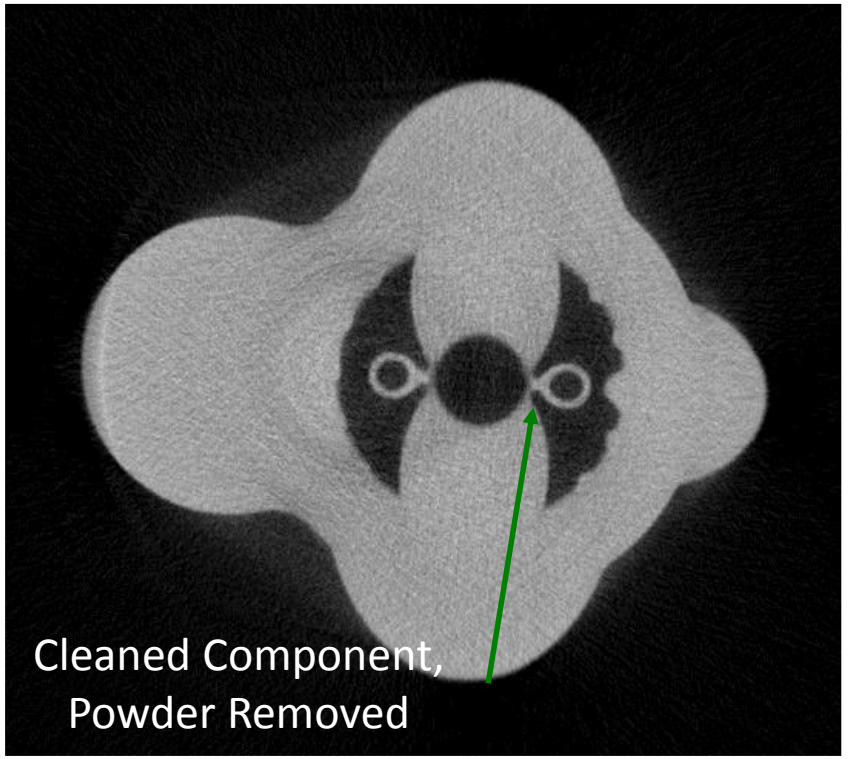
Inconel 718 powder was used to dope component #1 by adding powder into the top inlet holes. The part was then shaken for several minutes, then flipped for additional shaking as a means to work the powder into the component.

Powder deposition occurred in different areas as compared to the accrual locations of "As Received" test articles. As a result, the doping process does not appear to represent actual AM powder entrapment mechanisms. It may, however, represent powder dispersal during handling prior to post production processing.

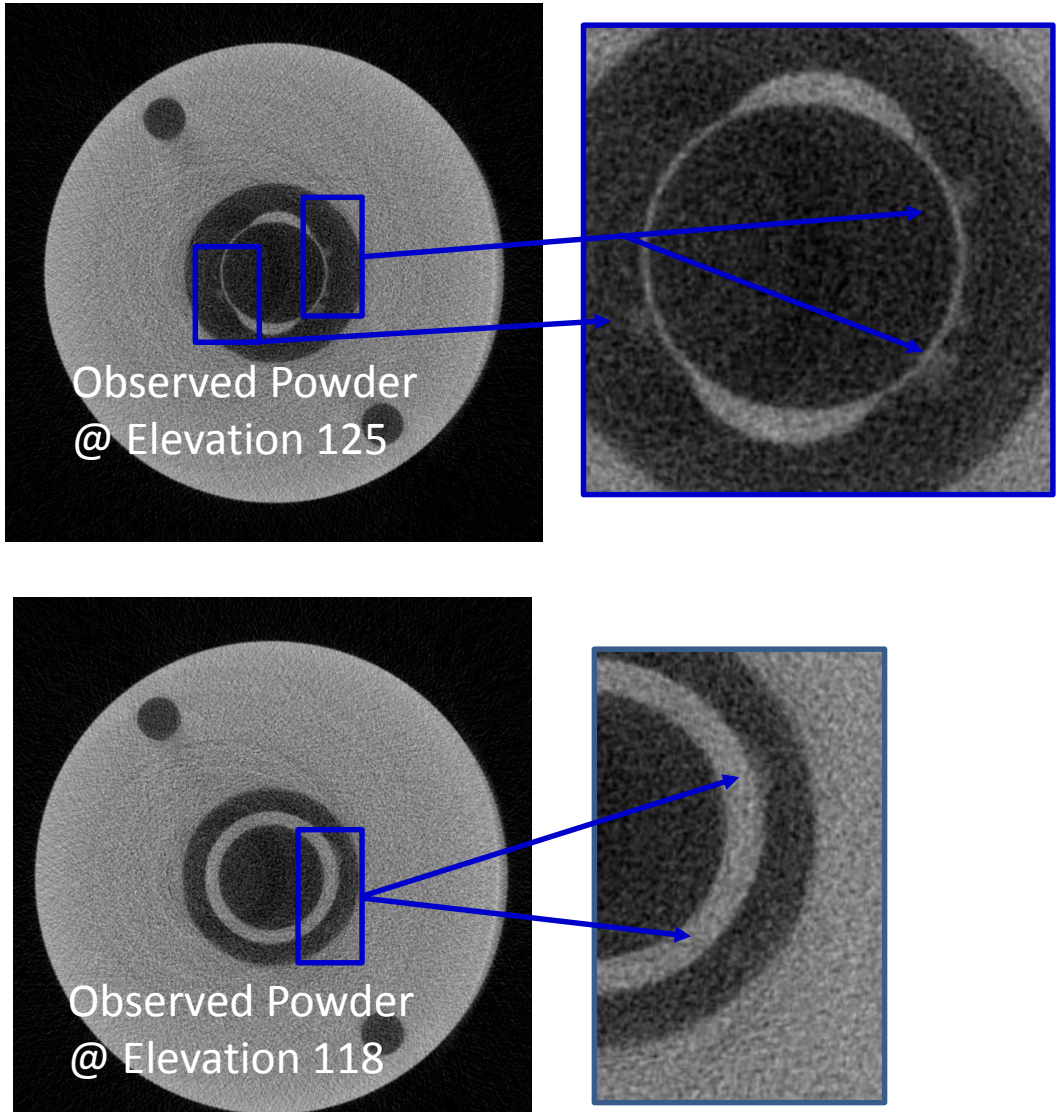




Trapped Powder Observed @ Elevation 136

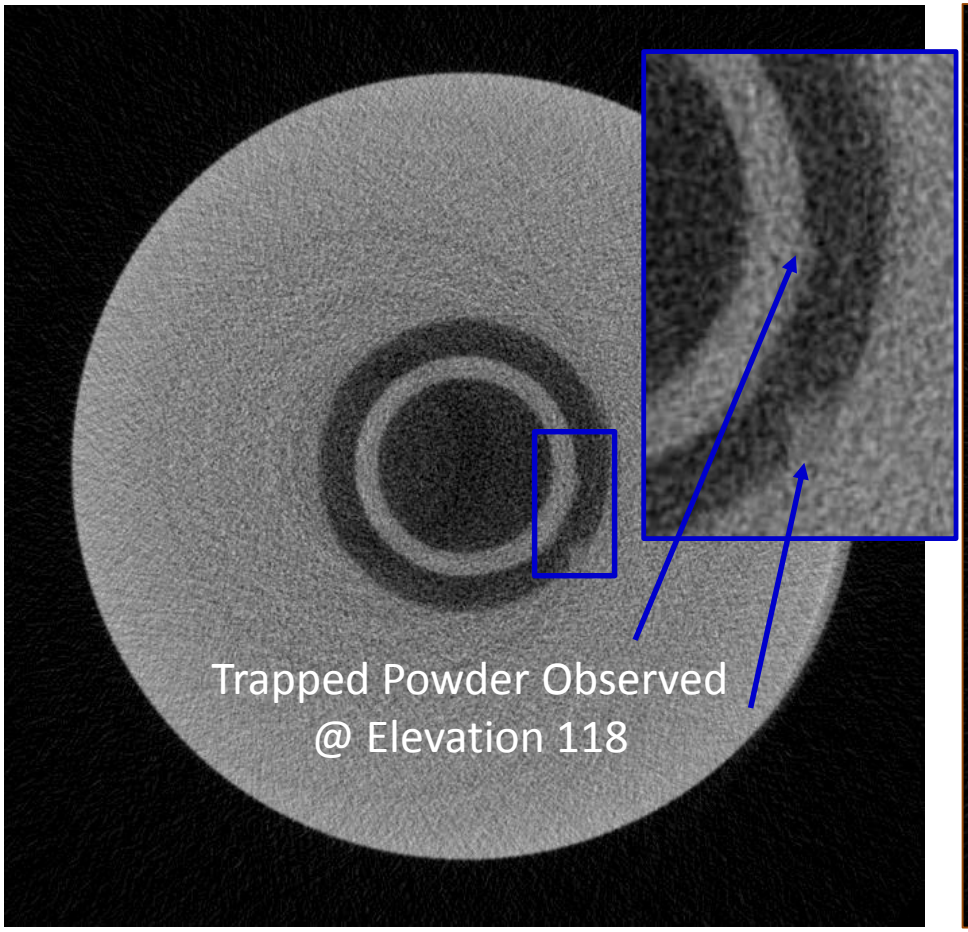


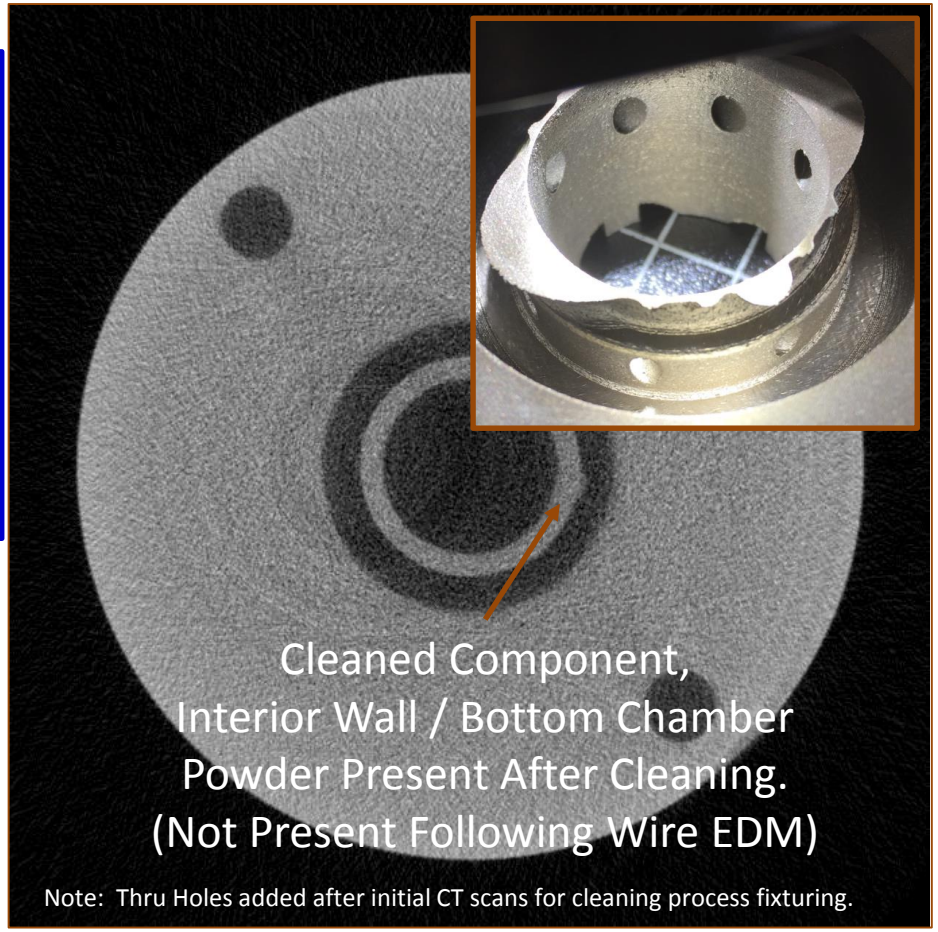
Component # 1 Analysis – Doped VS. Cleaned



Component # 2 Analysis – As Received VS. Cleaned

Powder was observed in two locations. Cleaning removed powder at one location but not at the interior wall / bottom chamber surface. A wire EDM cut of the affected zone did not show the presence of any mechanical defect, thereby indicating that the artifact in question was most likely powder.

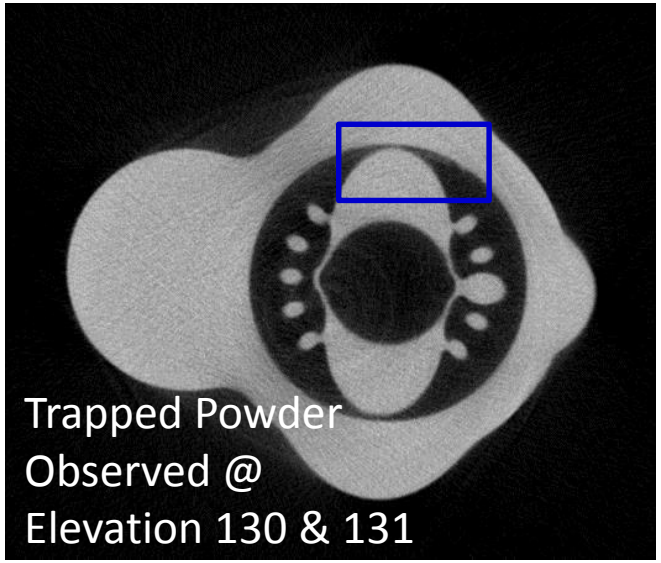


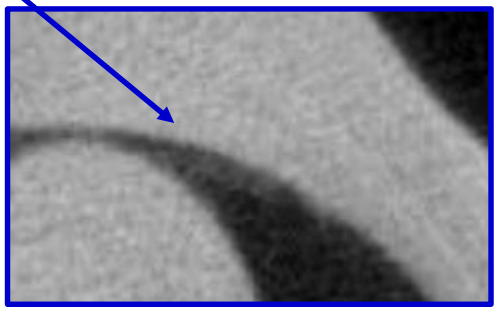


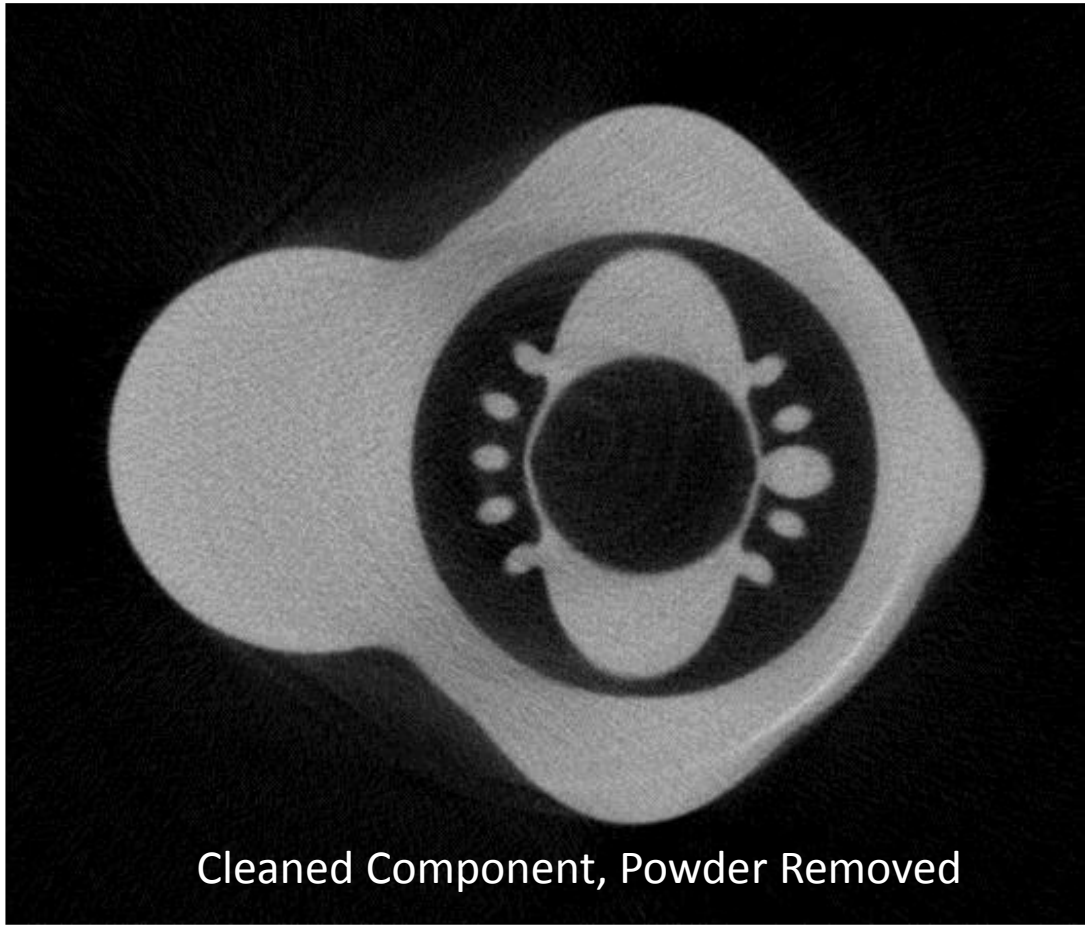
Component # 3 Analysis – As Received VS. Cleaned

Powder observed at the main cavity side wall on the upper corner.

Following cleaning, the powder is absent.

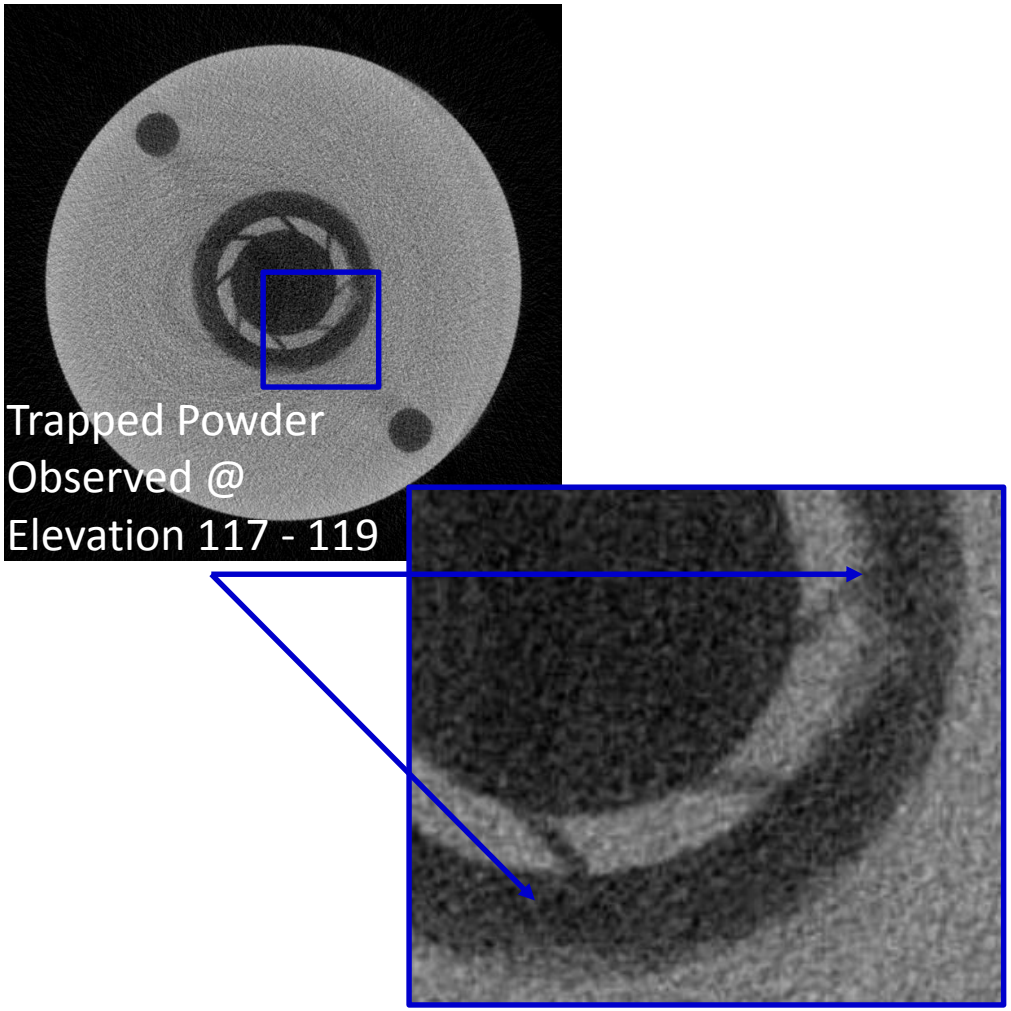


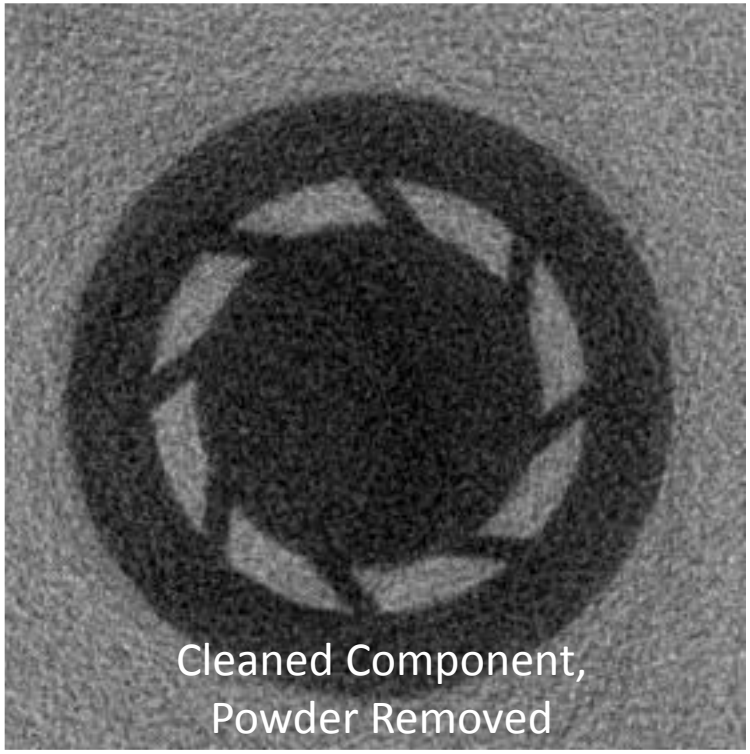




Component # 4 Analysis – As Received / Doped VS. Cleaned

Powder observed at the bottom main cavity in two locations, cavity angled outlet and at the exterior wall. Remnant powder is absent following cleaning.





Acknowledgements

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Questions?

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